Document de travail
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CA as a potential alternatives to mining agriculture in Kampong Cham uplands in Cambodia.

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Introduction

Kampong Cham is known to be a prosperous province, due to the presence of the agronomic quality of the red soils and the large-sized rubber plantations. Nevertheless, this picture masks a situation far less favorable to upland agriculture. A study of the agrarian system[1] in the south of Damber plateau in the Konpong Cham province has been implemented in 2009 by F.Thomas and P.Sophakphokea that includes as well previous analysis S Le Davadic (2009), L.Feintrenie, C.Jacqumin and E Penot (2004) (see Figure 1).

1. General description of the studied area (south of Damber plateaux)

The plateau areas of Kampong Cham province have very different agronomic capacities. 3 main agro-systems can be identified:

- Upper plateaus with red soils (basaltic plateaus). These areas are often planted in rubber trees.
- Intermediary plateaus and plateaus borders where brown stony soils are the most frequents. On this kind of soils, agriculture is more based on annual crops. The studied area is situated on these kinds of soils.
- Sandy areas characterized by not sustainable swidden cultivation practices (forest clearing, 5-10 years of annual crops, then rubber tree or cashew tree plantations before selling and leaving the lands).

The south of Damber plateau, situated in Damber and Ponhea Kreak districts, is representative of the plateaus borders. Soils are mainly brown and stony, so soil fertility is pretty poor. Villages are located near the rice fields (they cover 30 % to 70 % of village surface). 5 villages have been selected and situated on a length of 12 km et 4 administrative communes (*khum)*(Map n° 2).

[1] The agrarian system is defined as "a way to farm the territory, historically made up and sustainable, a system of force of production (a technical system), adapted to the bioclimatic conditions of a given space and which meets the current social needs" (M.Mazoyer, 1987).

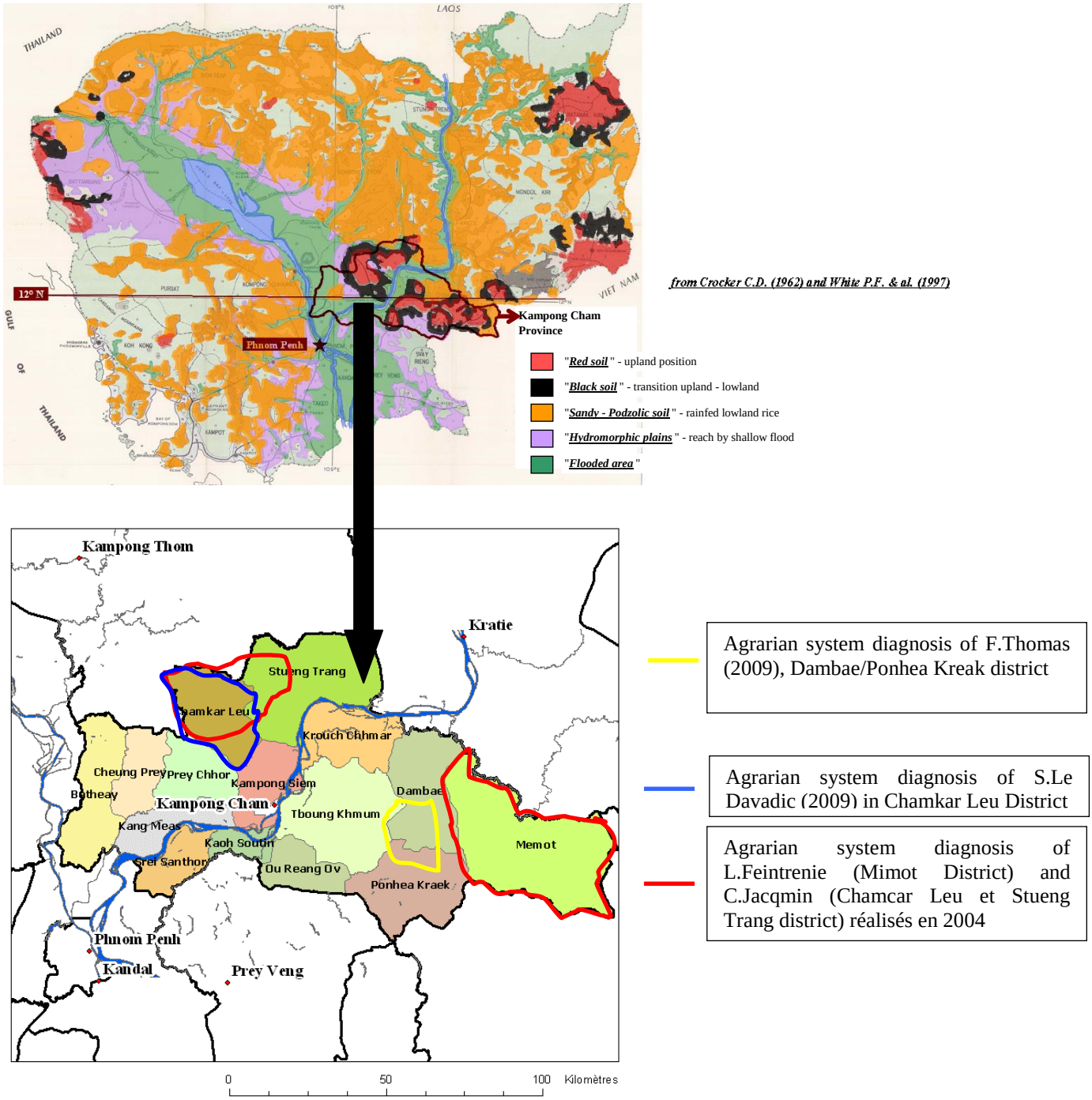
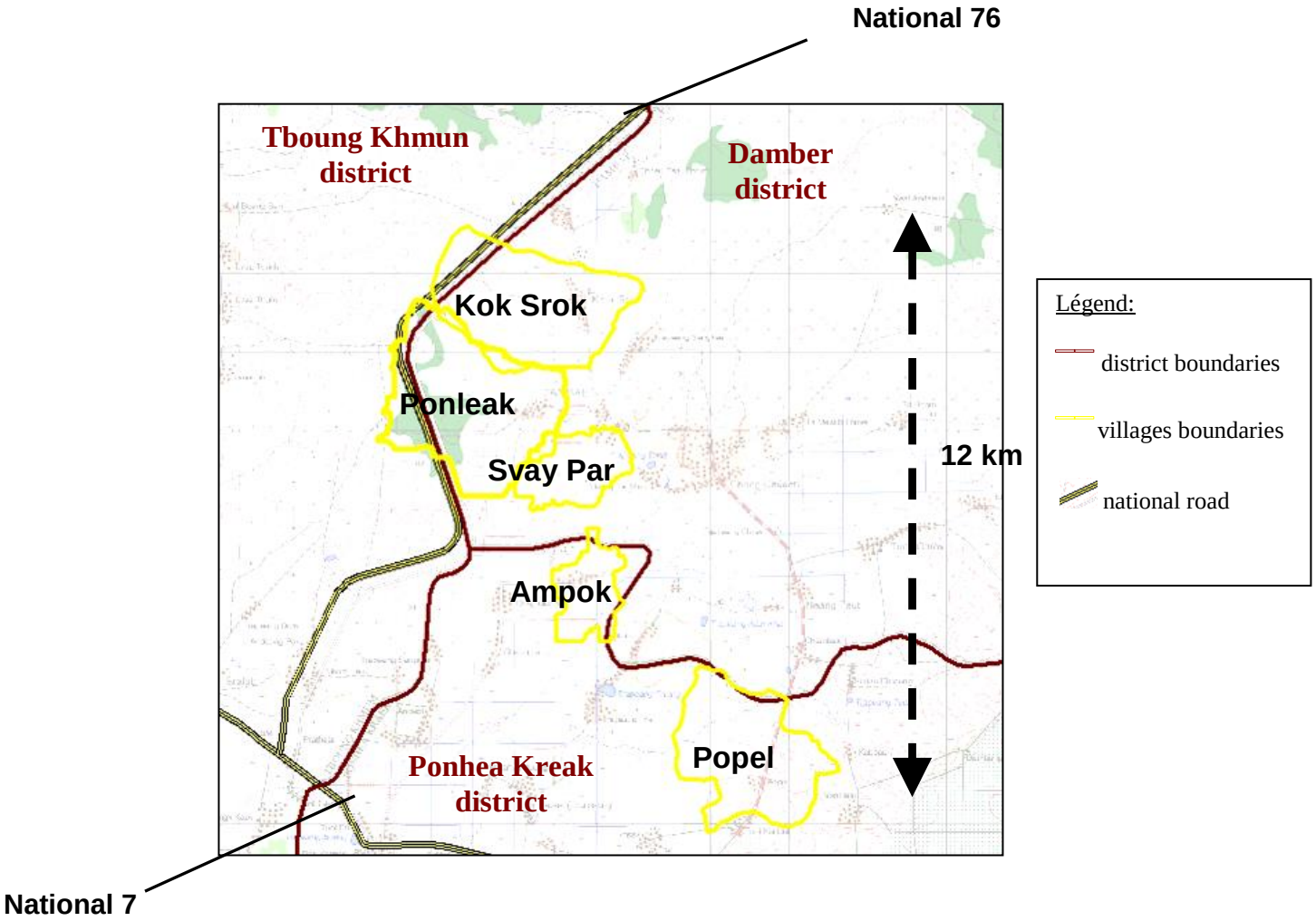


Figure 1 : Main "agricultural domains" and soil types in Kampong Cham province



Map n° 2: the study area.

2. Social differentiation leading to emigration

2.1 Introduction

Until 1920, the population was very scarce. Most farmers live in rice-growing lower plains. Food consummation was lower than nowadays. After 1920, French rubber-growing firms settle down in the virgin plateaus forests, particularly on red basaltic soils. After 1940, population pressure began to increase with both the increase in population of rice-growing plains and immigrants who began to clear forest. The most accessible land is located in the western border, as the eastern part of the province is still scarcely settled before the beginning of the war in 1969. The Vietnam War spreads to the East Cambodia after the decision of bombing the border zone in1969 supposedly hostile villages. Between 300 000 and 600 000 people died. Many rice fields, livestock and rubber plantations have been destroyed. Such attitude boosted the "Khmers rouges" offensive and importance in the area. By 1972, they were controlling 60 % of Cambodia. Collectivization of means of production and of the entire society was established sooner in the region than in the rest of the country, around 1971. Kampong Cham province was indeed one of the very first "Khmers rouges" stronghold.

Population control, standardization of agricultural practices, collectivization of all livestock led to global failure of production. Most upland "*chamcars"* were not anymore cultivated.
Ultimately the management of the "plateau" areas of Kampong Cham was quite different from the rest of the country. Indeed, as part of the "East Zone" (*Bophear*), the Khmer rouge leaders were more flexible and consequently, local farmers suffered far less during this troubled period. Recolonization occurred after 1978 at the fall of the khmer rouges. After 1979, refugees, urban emigrants and former local peasants displace by the bombings came back in the area with few animals and reoccupy land creating a real problem on land status and access. increase the difficulty. After 1980, the State re-organizes land redistribution, supposedly on an egalitarian basis, according to the number of people per family. This policy favored large family against small families (Jacqmin, 2004). Farmers with large family who recover the surviving animals and part of the land get rich sooner at the expenses of the others. In some villages where collectivization was poor, farmers refused to implement the law and choose to recover their land they owned before the troubles.
After 1986, rice market liberalization and farm re-monetization established a true return to market economy. Land redistribution ended up at the end of the 1980's. For smallholders, land property rights recognition signifies land security and the possibility to do long term investments. The 1990's were characterized by a strong liberal policy in order to be admitted in WCO. At the country scale, foreign trade has been multiplied by 13 between 1990 and 2000 (De Vienne, 2008). As a consequence, competition increases with the neighboring Vietnamese and Thai agriculture, especially for vegetable, poultry and pork industry. Meantime, the increase of population (multiplied by 2 in 20 years) led to land scattering trough the transmission of property by inheritance and an increase in land prices.
In the absence of a real national agricultural policy to balance such trends, these phenomena develop a growing social differentiation with "rich farmers" and "landless farmers". Once all remaining available land is being cleared and cropped, any increase in population leads mechanically to a decrease in farms areas, and so to migration. Kampong Cham province, which has long been a welcoming land covered with forest, has now a negative migration balance, as migration shifts to pioneer fronts at the North. (Le Davadic, 2009).

2.2 Insecurity has long limited the development of the area

Damber/Ponhea Kreak region is characterized by a prolonged insecurity situation. At the end of war, the area was still not pacified, and the administrations headquarter of the Damber district was even burnt by former "Khmers rouges" in the middle of the 1980ies. Bunch of outlaws hidden in the forests harassed villages and roads. They stole harvest, possessions, and above all animals. Capitalization possibilities were put off by those robberies. "*It was impossible to have a motorbike because it would have been stolen*". This situation also discouraged the development of fragile crops, such as fruit trees. In such conditions, results of work and investments are precarious and uncertain, and farmers choose prudential strategy such as annual crop growing and self sufficiency. Situation got better since 2000 and can at the moment be considered good enough to make business.

Agriculture of basaltic uplands is characterized during the 2000ies by the speeding up of the social differentiation started during the 1990ies. The richest farmers (>2,5ha) buy mechanized equipment: tractor for uplands and power tiller for lowlands. At the contrary, smallholders' situation keeps on deteriorating, all the more aggravated since the price of land and rice increase. "No lands" farmers get more and more numerous. Despite the introduction of motorized mechanization, technical progresses are rare. Agricultural practices are pretty similar to the ones observed by Delvert in 1950. On uplands, in the absence of fertilization, yields in soybean and maize decrease, and the cassava (very hardy) spreads very fast

(according to FAO, production has been multiplied by 15 between 2000 and 2007 in Cambodia).
At the same time, experts emphasize a general trend for perennial crops, especially rubber tree, while rubber price follows a great increase. At the contrary of big state plantations, which are almost exclusively planted on red soils, those new smallholder plantations are grown on brown stony or sandy soils. Finally, decrease in yields of annual crops, combined with a constant increase in land prices, lead plateaus agriculture to a crisis situation. Rubber tree seems to offer a solution to the depletion of soil fertility, but its adaptation to pedological and economics context is still doubtful.

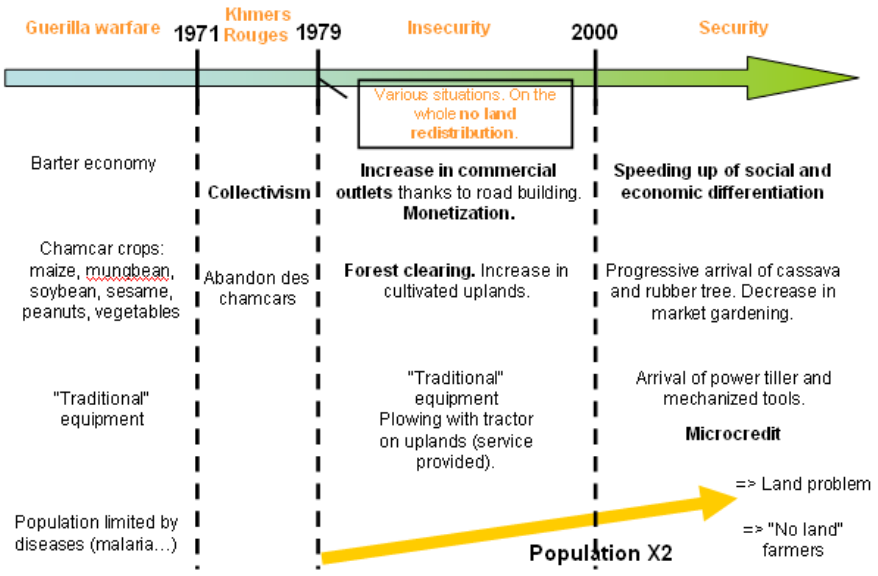


Figure 2: Damber history summary

2.3 An agricultural history characterized by radical orientations

Cassava and rubber tree: two key crops

Cassava was introduced in the middle of the 1990ies. Its spreading has been boosted by a dramatic price rise after 2005 (see **Erreur ! Source du renvoi introuvable.**) and has supplanted the former annual cropping systems (sesame/soybean and mungbean/maize essentially). At the same time, **rubber tree** spread in the area following 2 dynamics:

- In **villages with red soils:** farmers have already experienced rubber trees. They decide to invest only on red soils, and they take into account the high difficulty of this kind of investments (only rich farmers plant). The Rubber Smallholders Development Project (RSDP) seems to have achieved his aim.
- In **villages with no red soils:** farmers haven't experienced rubber trees because RSDP has never worked in these areas. They had a very positive feeling about rubber trees. When rubber prices rose, a lot of smallholder decided to plant rubber trees. In a short term, half of the upland surfaces of some village will be covered by rubber trees. Sometimes, all the uplands fields of one farm are converted to rubber production! Moreover, those plantations are located on sandy and brown stony soils which aren't suitable for rubber trees (see box p10).

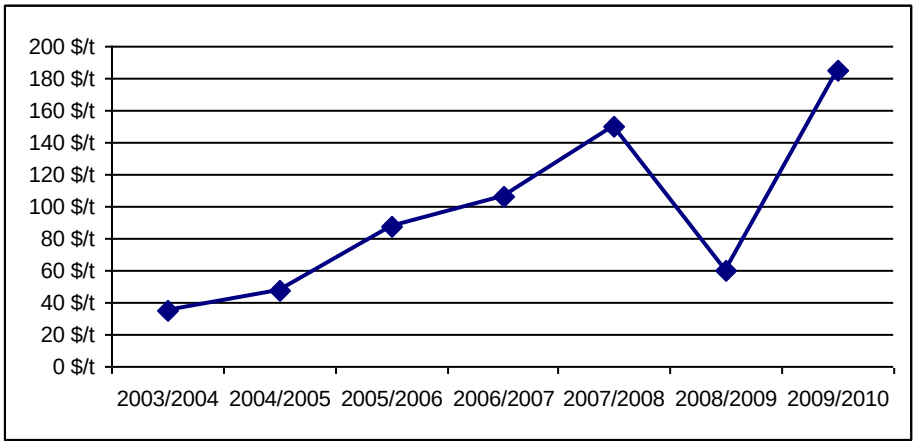


Figure 3 : Evolution of cassava price ("category 2", Ponleak village).

Important questions remain about economic results of rubber tree planted on sandy or brown stony soils. Soils are often depleted, fertilizers are rarely spread, and cassava and rubber are always grown together the first years (competition for light, nutrient, and water). On brown stony soils: Plantations seems to be doomed because of the low depth of soils (and so low water availability). First results of rubber tree planted in 2003 confirm this diagnosis: about half of the planted trees died. On sandy soils: Harvesting date is going to be delayed because of the agricultural practices and very low soil fertility. Modeling shows that farmers will not be able to sustain the investment, and will certainly cut the trees to grow annual crops if cassava prices stay high. So perspectives are very somber. Other studies are necessary (see modeling p14) to go further into this subject because rubber tree is a key success factor for plateaus agriculture. Moreover, it's important to notice that rubber tree plantations on sandy soils are sometimes successful in other countries.

Other cropping systems

During this period, market gardening have seen its surfaces decrease, essentially because of the Vietnamese competition. Most of the cashew tree plantations were planted around 2000, when the kg of cashew nuts was about 1 $. Price have then felt in under 0,5 $/kg, which has led farmers to cut their trees in order to plant cassava or rubber. Still can be found some residual plantations. The 2 cycles crops (sesame/soybean, mongbean/maize essentially), which first cycle suffers a lot of unpredictable rains, have progressively disappeared. In the absence of fertilization, their yields were decreasing, leading to the abandon of the first cycle crop (sesame or mongbean) on the poorest soils.

This different dynamics have combined to lead to the predominance of 2 cropping systems on uplands: cassava monoculture and rubber tree (if we don't include residual cashew trees plantations). We estimate that cassava is grown on about 65 % of uplands, rubber tree on 25% and cashew trees on 10%. So the change is radical compared to the last 50 years.

As for Mimot plateau, nearness of Vietnam is a determinant geographic factor (Feintrenie, 2004). Production is usually sold to middlemen who transport it to Vietnam. Farmers can cover the distance to Vietnam in 45 minutes with motorbike. So production is sometime sold directly at the frontier. Nevertheless, jobs opportunities are few in the area but for rubber tree worker (no industry). As we have already said, Vietnam war spread on the border zone and has had huge consequences on agriculture and history. The last 5 years, Vietnam market has

strongly influenced the fast spreading of cassava and rubber trees. These 2 crops are at the present the 2 main crops grown in the area.

	2000 => 2005	2005 => 2007	2008-2009	2009-2010
Market/Prices	Cashew nut ↗ Rubber ↘	Cashew nut ↘ Cassava/ Rubber ↗ Vegetables ↘	Rubber = Cassava ↘ Rice ↗	Rubber = Cassava ↗ Rice =
Exterior influence	Beginning of RSDP (only villages with red soils).	End of the RSDP. Microcredit development. Competition of Vietnamese vegetables.	PADAC Project.	Subsidies to biofuel in Vietnam. PADAC Project.
Agricultural dynamic	Cashew tree plantations. Rubber tree plantations on red soils.	Cutting of cashew trees. Rubber tree plantations on all kind of soils. Spreading of cassava. End of market gardening.	Continuation of rubber tree plantations and cassava monoculture.	Continuation of rubber tree plantations and cassava monoculture. CA systems.

Table 1: Crop evolution during the last 10 years

Very vulnerable livestock systems

Livestock systems are all characterized by their high vulnerability to disease. So disease prevention should be the first aim of development programs dealing with livestock. For poultry, the solution could be very simple (coop building and cleaning). For pigs and bovines, vaccination and drugs are already used, but their quality should be guaranteed. Almost all families breed chickens or ducks at small scale (less than 10 animals). They are always self-consumed. Farmers are starting to breed intensively ducks near from the national roads.

We can distinguish 2 livestock systems for pigs:

- An extensive one: piglets are bought at the age of 2 weeks and are fattened with pig food (Green Feed) until they are about 80kg at the age of 8 years. This kind of livestock systems can have good results if prices are high. But as for the other markets, price fluctuates fast (depending on importations from Vietnam). Nowadays, these livestock systems aren't profitable.
- An intensive one, based on huller machine and rice wine production. This kind of livestock systems can breed 30 pigs/year and gain 750$/year, even with low prices at the present.

The main diseases are pig pest, pasteurellosis, salmonellosis and Aujesky disease.

Bovines and bubalines are getting less and less numerous because of 2 main factors:

- - Competition with power tiller for fields works
- - Decreasing of pasture period because of the long vegetative cycle of cassava (from March to January).

However, cattle still represent an useful long term saving for farmers, even if it is also very sensible to disease as pasteurellosis, foot and mouth disease and *Clostridium* infections.

Children are also compulsory for keeping the cows. CA systems can curve the trend of cattle decreasing by providing some forage (*Stylosanthes* and *Brachiarria*). A study is going on to go further into this question and the results are supposed to be very impressive.

Conclusion

In a context of economic liberalization, and of increase in economic productivity of lands (thanks to cassava high prices), the differentiation process speeds up, leading to the arrival of rich farmers who focus on cash crops and perennial crops (following the same. process than in Chamcar Leu district). At the same time, the doubling of population since 1980 has increased the price of lands. A "no land" farmer class appeared. Definitive emigration in the direction of Kratie and Mondolkiri province is more and more frequent**.** In the absence of innovations and if cassava prices stay low, the area seems to reach the saturation point.

3 Farm typology

3.1 Presentation

The aim of a typology is to represent the whole diversity of farms in our area with a few categories (types). The typology is based on the study of a limited number of farms (50 in our case). Main criteria for the identified typology are soils localization (upland or lowland) and the farm area.

- Soils localization: Allocation of lands in lowland (rice) or upland (cassava, rubber, or cashew trees) can explain farmer's strategies.
- Farm area: Because the soils are quite homogeneous, farm area criteria is an easy way to estimate capital and wealth of a farm.

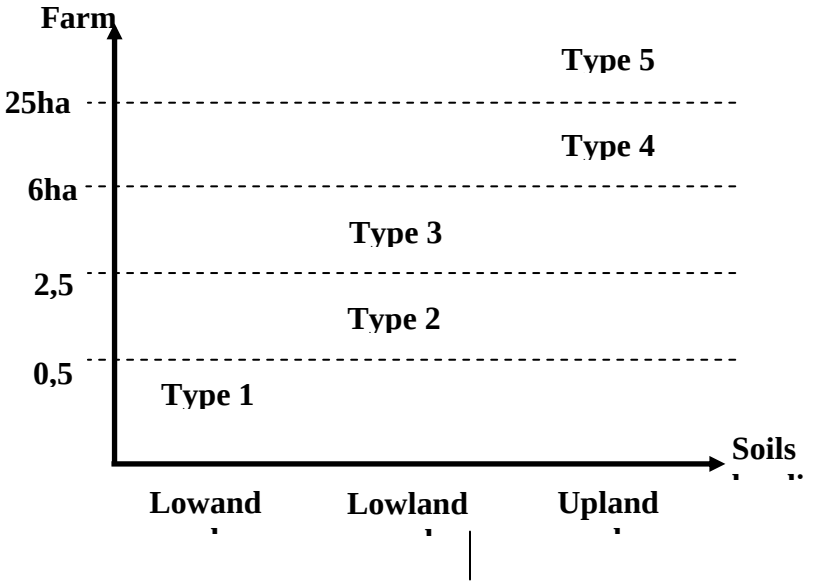


Figure 4 : Identified typology in function of farm area and soil localization

Type	1	2	3	4	6
Proportion	20%	53%	25%	2%	-

Table 2: Approximation of the repartition of types in the studied area

3.2 Types description

Type 1 Small farms with no upland

These farms are the most precarious. They don't own any upland. Their whole production is self consumed. They sometimes don't even possess lands and are obliged to rent some. Their management is actually more similar to "no lands" farmers than to other types of farms because most of their incomes come from farmworker daily jobs. They logically opt for risk reduction strategy (rice growing). They are always under the "poverty line" (estimate at 638 $/year on the basis of an "average" family of 5 people). That means they have to sell their lands and leave agriculture in the short term (unless there are only 2 or 3 persons in the family) or find an off farm job.

Type 2: Medium farms with uplands and lowlands

The type 2 is the first in number of farms. These farms of "average" area (between 1 and 2,5 ha) own a traditional equipment, and generally more rice fields than chamcar fields. Pork activities are scarce and very often in deficit because of health problem and price variation. These farms are just above the "poverty line" thanks to their daily jobs incomes. As a consequence, their future depends on price fluctuations (especially in cassava). They are also very vulnerable to unpredictable events such as disease, bad harvest… which can lead to a fast decapitalization. For example, cassava fall in price in 2008 lead them to a difficult situation. These farmers sometimes take important risks:

- In some villages, some farmers opted for a long term strategy by planting rubber trees. These plantations are made on poor soils (sandy or brown). Our projections using modeling tool are worrying (see the box below).
- Other farmers choose to rent lands out of their village in order to cultivate cassava. Usually, rented areas are about 1,5 ha/family but some farmers rent 5 ha. These lands are poor, usually located on pioneer front, so very far from their home. The investment, carried on thanks to microcredit, turned out to be very bad in 2008/2009 because of the fall in cassava prices ("stranglehold effect").

After a good period during which they have improved their living conditions (electric lighting, television…), install their children or invest in rubber tree, we observe that their future is not sure if cassava prices are low (as in 2008/2009). The lack of diversification of these farms explains their low resilience. In long term, because of not sustainable agricultural practices, we wonder how much time these smallholders will meet their needs.

Type 3: Big farms with uplands and lowlands

Type 3 represent rich farmers who own more than 2,5 ha. These families are far above the poverty line, even in 2008/2009. Investments they made the last years in lands, equipment, or livestock ensure them security against unpredictable events. Indeed, their capital is far higher than "type 2 farms". Nevertheless, they keep rice fields in order to ensure their food security. They usually own o power tiller, which allow them to realize their work by themselves and to sell service provision. The trend for rubber tree planting is very strong for this type. Apart from red soils, the same questions remain about the farmer capacity to sustain the investment.
Motomechanization has been booming the last 10 years. We estimate that 20% of farms now own a power tiller. The service provision for preparing the soil is very widespread. In rice fields, about 2/3 of plowing and harrowing are done this way. On uplands, all the fields are plowed by service provider. This is a favorable factor for CA based systems because the

purchase of specialized drilling machine could be done by the richest service providers, so smaller farmers don't need to invest in expensive equipment to grow CA system.

Type 4: Big farms with no lowlands

This type is not widespread (about 30 families in the 5 villages). Area/worker is very high (about 6 ha/worker), so these farms are interested in extensive in work cropping systems such as perennial trees. As a consequence, a lot of farmers convert all their chamcar lands into rubber trees. Moreover, they often possess good lands (red soils). Nevertheless, the low productivity of rice growing put them off to invest in lowlands. They own almost no equipment, apart from the tools needed to grow rubber tree. In the absence of rice growing, the purchase of a power tiller is not justified.

These farms also often earn money thanks to diversification (see the box below). In the future, these farmers will surely get richer and richer as the differentiation processes go on. Moreover, their children have often the possibility to pursue studies until university (we can consider them as an "emerging middle class").

Some farmers specialize in off farm or livestock activities: transport, production of rice wine combine with intensive pork raising, shop…These activities have been booming since 2000 and provide big incomes which are reinvested in lands. More than 5 % of farmers earn more than half of their incomes thanks to such activities (type 2 and 3 essentially).

Type 5: Big capitalistic farms

45ha of Ponleak village are grown by an exterior investor who live most of the year in Phnom Penh. This farmer grows various crops on good quality soils: rubber tree, cassava, fruit trees. He has no animals but he's got heavy equipment: tractor, truck, and 9 permanent workers. We decide to consider him as a type because this kind of capitalistic[2] farms seems to exist in the region.

4 Diminution of soil fertility leads agriculture to crisis

4.1 the pedological context

In order to be synthetic, we distinguish 3 soils types: red soils, brown stony soils and sandy soils. This soil typology can be considered pretty imprecise by specialists but gives an overview of uplands pedology.The 3 main soils have distinct agronomic capacities:

- **Red soils** (*dey krohom*) are known to be very fertile and to reach world best yields for rubber. All the red soils have been cleared and are now cultivated. The dry cassava yields are about 14 t/ha. Their price can reach 6000 $/ha in Chamcar Leu district, which is the highest price in the country for agricultural land (Le Davadic, 2009). Other names: Nitrosols, Ferrasols.
- **Brown stony soils** (*kampong siem*) are usually situated on upland borders, on both uplands and lowlands. These soils are easier to work than red soil but nevertheless have a good fertility. But their lower content in clay implies that their yields decrease faster. The cassava yield is very dependant on the level of depletion (between 6 t/ha et 12 t/ha of dry cassava). Moreover, they have strong potassium deficiency; which is a big problem because cassava exports a lot of potassium. Other names: Regurs.

[2] Following definition by Bergeret and Dufumier in the Mémento de l'agronome (2006)

- **Sandy soils** (*le bay ksad*) can be found on uplands (white color) or lowlands (pink color). They are very sandy (about 80 % of sand). Those soils are very poor and even said podzolic. They can't sustain an agriculture based on annual crops without fertilization for a long time. The dry cassava yields reach 4t/ha after 4 years of monoculture. Nevertheless, about 20 % of them benefits from high clay content and have far better agronomic capacities. Other names: Alfisols, Ultisols, Planosols, hydromophic cultural.

The position de the soils type usually depends on altitude. Sandy soils are on lower lands, often in lowlands to grow rice. Brown soils are in intermediary position and are the more often not flooded. Red soils are on the upper lands (after 70m) and are never flooded. (see Figure 5). We can also find big sandy areas (for example at the North of Damber plateau).

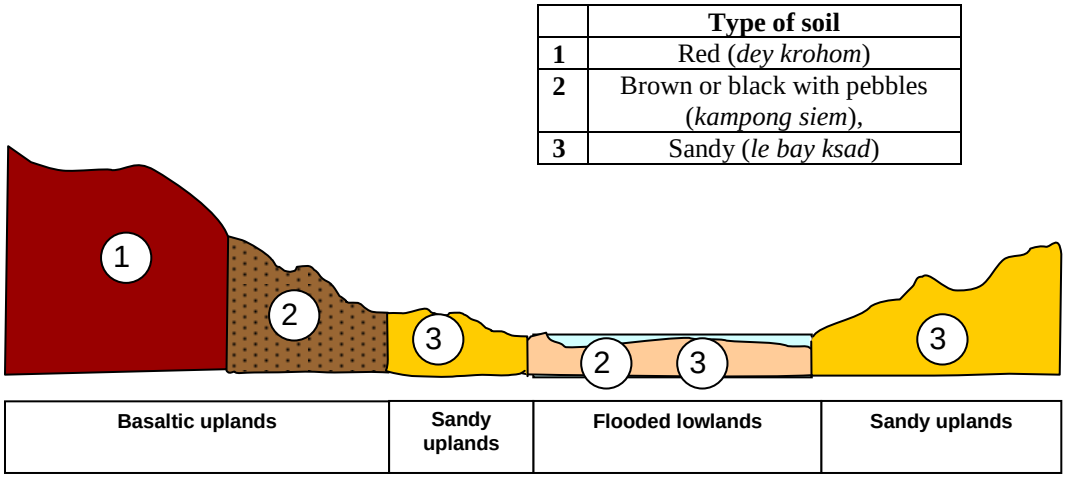


Figure 5 : Soil transect of Kampong Cham province uplands

4.2 A decreasing fertility

In rice fields

In rice fields, fertilization practices are insufficient to maintain yields:

- farmers use cow dung and not manure (cow dung + straw)
- inputs are concentrated on nurseries and are scarce on rice fields
- chemical fertilizers are not used

Despite all those defaults, it seems difficult at the present to modify these practices. They are indeed rationally optimized to get the maximum efficiency with limited resources. Straw that could be used to make manure is better used for feeding animals. It is justified to concentrate inputs on the nursery because it's the most critical stage for rice growing. Finally, chemical fertilizer trials aren't very successful when it comes to farmers. Barring subsidies for fertilizers, the best solution could be to give to farmers the possibility to produce manure by substituting straw for another food in livestock feeding. The mowing of CA associated crops (*Stylosanthes guianensis* or *Bracchiari ruziziensis*) could fulfill this function. As a consequence, CA based systems would indirectly participate to sustain rice fields fertility.

In uplands

The study of agricultural history shows that plateaus soils have been deeply plowed with tractor for 15 years. Before the arrival of tractor, the plowing was difficult and only superficial. Combined with 2 cycles cropping, and no fertilization, this intensive exploitation leads to a decrease in soil chemical fertility and to physical problems such as soil compaction. Erosion problems are also locally serious (gullies…). Since a couple of years, cassava cropping exports a lot of nutrients and aggravates the problem (see Table 3). Nutrient exportations are particularly strong for Potassium (K) which availability is low in area soils.

	Tuber	Wood	Total
N	77kg/ha	50kg/ha	127kg/ha
P2O5	19kg/ha	13kg/ha	32kg/ha
K2O	110kg/ha	39kg/ha	**149kg/ha**
Ca	13kg/ha	9kg/ha	21kg/ha
Mg	3kg/ha	12kg/ha	15kg/ha

Table 3: Nutrient exportations for cassava cropping (yield = 10t dry cassava/ha). Source: Mémento de l'agronome

Examples of yield evolution for cassava monoculture show the **fragility of brown and sandy soils** (see Figure 6). Yields seem to stabilize at 6 t of dry cassava/ha for brown stony soils and 3,5 t of dry cassava/ha for sandy soils. On those soils, farmers exclude the possibility to go back on soybean and maize.

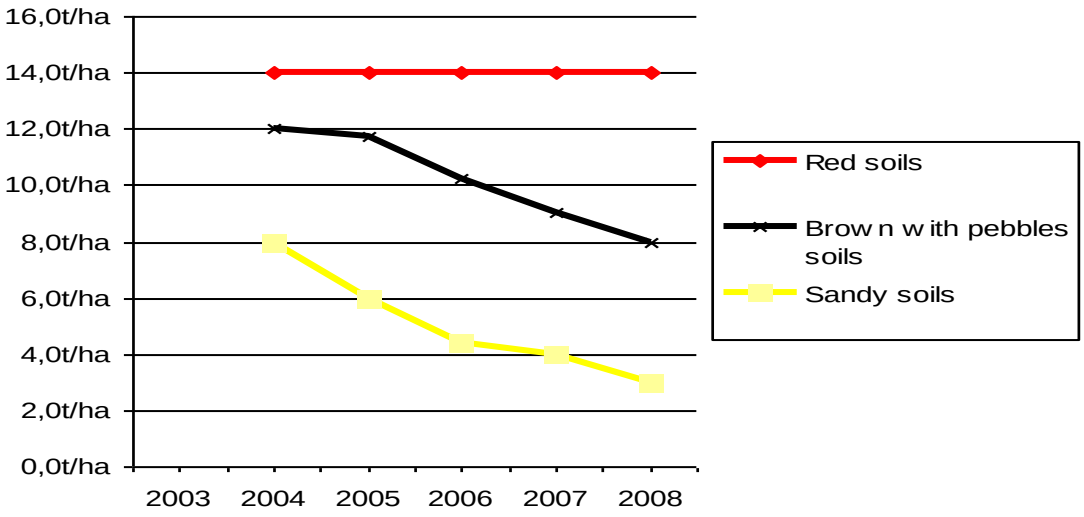


Figure 6 : Examples of yield evolution for cassava monoculture

To cope with these fertility problems, farmers plant perennial crops with deep roots. Has we have seen, cashew trees were cut when the prices fell in, and rubber trees are not suitable on all the soils and for all the farmers.

To compare the situation with Chamcar Leu, we can take a look at the Figure 7. Chamcar Leu soils are on the whole better than in our studied area. This difference in soil fertility leads to a difference in cropping systems: we observe at the moment in Chamcar Leu the same crops than 10 years ago in the south of Damber plateau. Nowadays, cassava is spreading only on the poorest soils of Chamcar Leu, but we can predict that cassava will be grown on more and more lands as the soil fertility will decrease.

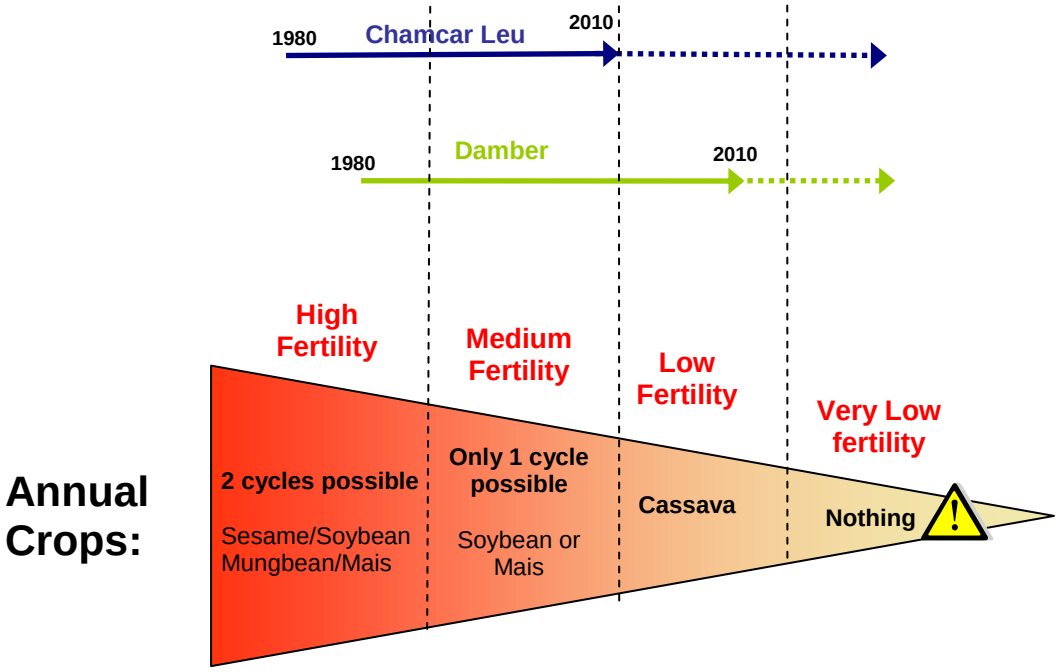


Figure 7 : Evolution of the annual crops and of the soil fertility between 1980 and 2010

5 Smallholders strategies:

In this fast changing context, we distinguish 4 kinds of strategies:

- **Risk reduction strategy (rice growing)**

Based on rice growing: Preferred by farmers who own small surfaces, and who look for food self sufficiency. Small farms opt for this strategy by default. Type 1, 2 and 3 are representative of this strategy. Type 4 and 5 are rich enough and don't need to ensure rice self-sufficiency.

- **Short term strategy (cassava monoculture)**

Farmers choose this strategy in order to get immediate incomes without investing in long term. But the monoculture of cassava leads to an inescapable decrease in incomes because of the decrease in yields (see graph below). Type 3 farms can survive but type 2 (50% of population) will disappear if cassava prices are low.

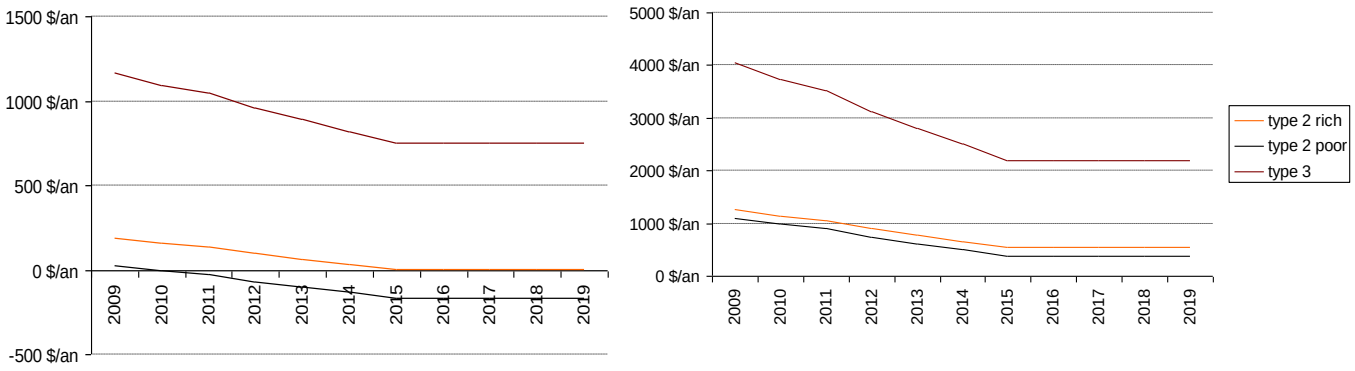
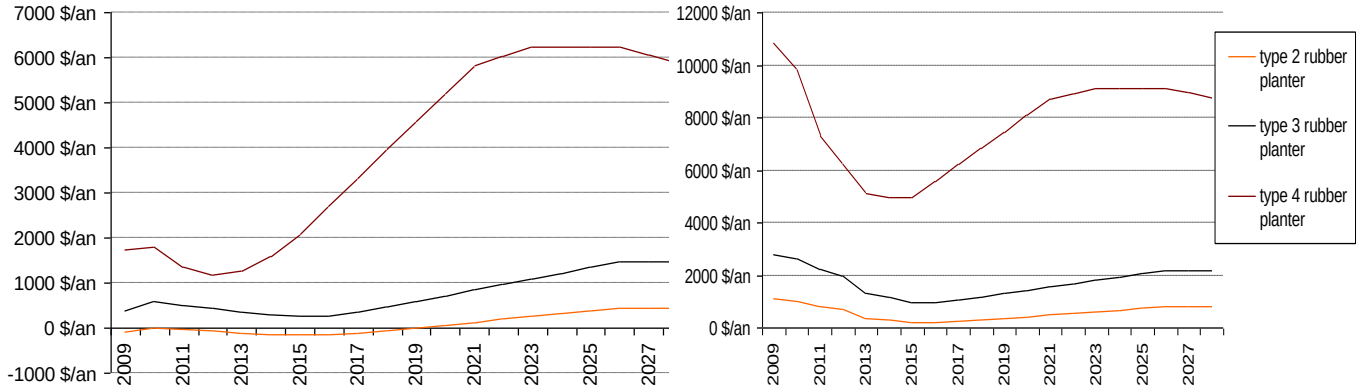


Figure 8 : Balance of type 2 and type 3 farmers on kampong siem soils.
Left: Cassava = 60$/$t_{dry}$ (2008/2009 prices).
Right: Cassava = 180$/$t_{dry}$ (2009/2010 prices).

Balance = incomes (including off farm) – outcomes (defined as the poverty line = 638$/year)

- **Long term strategy (rubber tree plantations)**

Smallholders who estimate that their investment capacities are sufficient choose to plant rubber tree. As a consequence, this strategy is the more often chosen by rich farmers (but as we have seen, poor farmers try). If we consider type 4 with red soil plantations and type 2 and 3 with sandy soil plantations, we can notice that the investment is very difficult for type 2, whatever the cassava price (see below). If cassava prices are low, it's even impossible for type 3. Type 4 has always enough incomes to sustain the investment in rubber plantation.
As a consequence, we expect to see farmers cut the trees or sell the plantations if cassava prices are low. If cassava prices are high, they will surely cut most of the trees in order to plant cassava instead of rubber tree. Finally, we expect type 2 and 3 farmers to cut their plantations and switch to short term strategy.



- **Diversification strategy:**

Farmers combine as much as possible the 3 first strategies in order to minimize risks (reorientation if fall in prices). Off farm activities, livestock activities, market gardening or a

residual cashew tree plantation are answers to the same needs. These activities can yield a huge profit (generally more than 700 $/year) and are getting more and more frequent. Moreover, smallholders try to combine as much as possible lowland and upland crops, apart from the richest farms that don't really care about food security.
To conclude, short-term strategy leads to soil depletion and long-term strategy are difficult to manage because return on investment is long. Farmers are looking for an intermediary solution on uplands.

6 CA based systems: a solution to the agricultural crisis?

A mid-term investment economically attractive

CA based systems ensure a fast improvement of soil fertility and a decreasing in weeding cost. Unlike rubber trees, CA systems have no immature period (period during which the tree is not producing). In other words, CA systems are mid-term investment. As long term investment seems too ambitious for the small farms, CA systems could seduce a lot of farmers, being an intermediary solution between short-term (cassava) and long-term (rubber trees) strategies.
According to our simulations (based on field and farmer data), CA systems are competitive with other cropping systems, whatever the price of cassava (see below). They even appear to be more attractive than rubber tree plantations! They appear to be more attractive on poor soils (kampong siem and sand) than on red soils, because soil potential improving is higher when soils are poor.

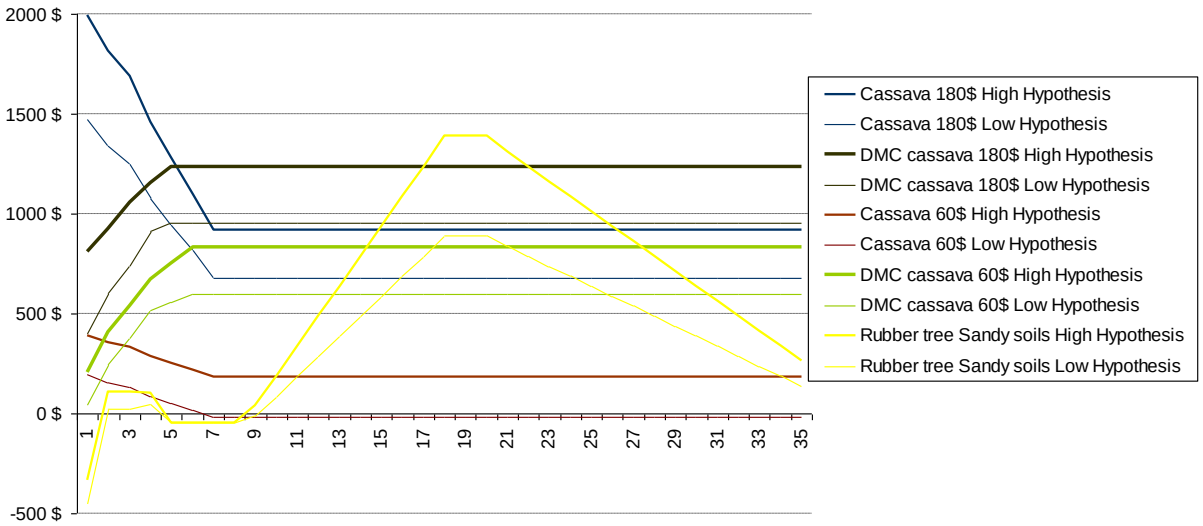


Figure 10 : Gross Margin comparison for cassava monoculture, CA systems and rubber tree plantations. Cassava and CA systems are on kampong siem soils, whereas rubber trees are on sandy soils. We simulate 2 prices hypothesis: cassava = 180 $/t$_{dry}$ and cassava = 60 $/t$_{dry}$.

Even on the poorest soils (sandy soils), CA systems succeed in providing enough money to type 2 smallholders to survive (i.e. stay above the poverty line) in 3 years, whereas they are doomed to failure if they continue cassava monoculture (see Figure 8).

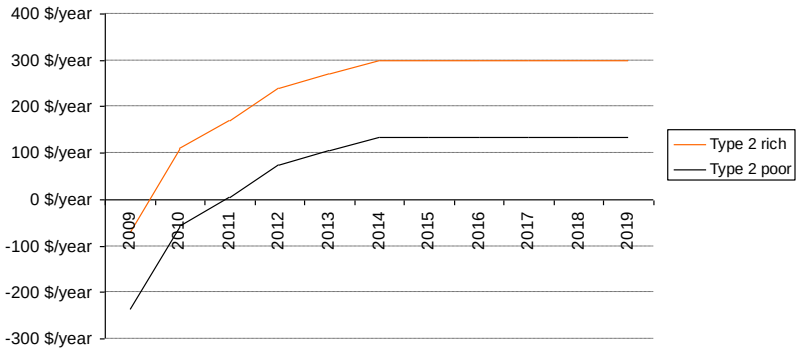


Figure 11 : Balance of type 2 farmers who grow CA systems on sandy soils. Cassava = 60 $/t$_{dry}$.

Cash flow: the main constraint:

If CA systems are proved to improve fast and appreciably farmer's incomes, they are **very intensive systems in input** compared to other cropping systems. It signifies that an investment in inputs (fertilizers, seeds…) is necessary at the beginning of the year to start the system. This cash funds may be difficult to find even if farmers are entirely refunded after the harvest, in particular if cassava prices and farmers cash fund are low (see Figure below).

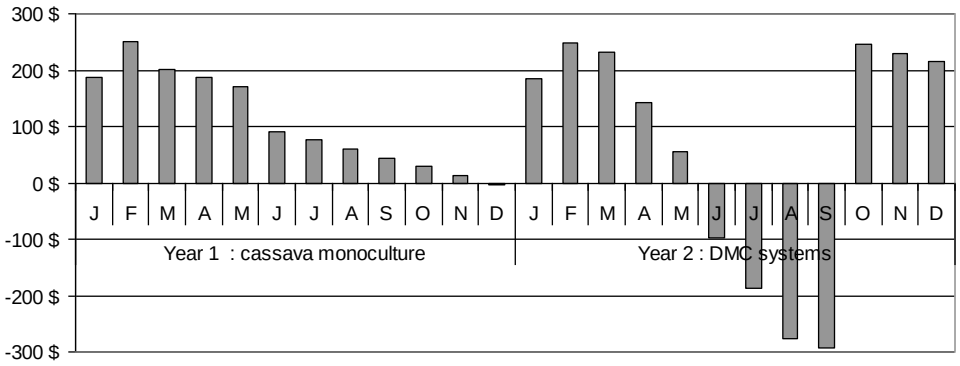


Figure 12 : Cash fund calendar of farmer growing cassava the first year and starting to grow CA systems the second year. Cassava = 60 $/t$_{dry}$.

PADAC project has already anticipated this problem and provide to CA farmers a cash advance of 260 $/ha financed by partner firm PROCONCO. Progressive conversion should also be considered for small farmers, as we have seen with rubber trees that they are likely to take dangerous risks.

Microcredit is frequently used by farmers to improve their cash fund during the year. It may be a good solution, but the risk is also high to put into debt the farmers. So a particular attention should be paid to this point.

Conclusion

CA systems seem to be an adapted solution to the agriculture crisis on Kampong Cham plateaus: they are mid-term investments and resolve problem of soil fertility.
Area history and modeling studies show that the market context will be very important. Whatever cassava prices, CA system are economically attractive, in particular on kampong siem and sandy soils. But to start growing CA systems, farmers need money funds. So it will be easier to start CA systems after one or several years of high cassava prices, when farmers will have recovered enough money to invest.
To adapt to this fast changing context, the best way for PADAC project is to plan a flexible and diversified offer. Project should also prevent from a possible "overheating" of CA systems favored by microcredit, similar to what we observe at the moment for rubber trees. Progressive conversion (starting on small fields) seems to be preferable.
Moreover, synergy is possible between CA systems and livestock systems (which isn't taken into account in our modeling). The use of improved forage resource should induce change in animal management (Boulakia et al., 2006): a progressive shift from the current long term herd maintenance (where animal represents a form of long term savings) to short term fattening (where livestock become a more productive capital). Those effects of the CA system are yet difficult to estimate and a study is going to shed light on this subject, but forecast are optimistic. The problem of pasture of CA fields by cattle seems to be resolving easily, as more and more farmers enclose their fields with fences.
To conclude, CA systems affect management at the field scale (yield, inputs…), at the farming system scale (interaction livestock/forage, labour/weeding…) and even at the village scale (pasture problems). Agrarian diagnosis and systemic analysis seem to provide the good framework to identify the ins and outs of CA systems based innovations, even if technical analysis may be necessary to go further in some questions.

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